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Characterisation of the 2-dimensional edge turbulence of RFX-mod experiment

M.Agostini[12], R.Cavazzana[1], F.Sattin[1], P.Scarin[1], G.Serianni[1], M.Spolaore[1], N.Vianello[1]

[1] *Consorzio RFX, Associazione EURATOM-ENEA sulla fusione, C.so Stati Uniti 4 35127, Padova, Italy*

[2]*Dipartimento di Fisica, Università di Padova, Padova, Italy*

The edge region of magnetised plasmas is characterised by strong fluctuations of density, temperature and electrostatic potential that are considered the main cause of the anomalous transport [1].

To study the edge structures at high frequency in the RFX-mod Reversed Field Pinch (RFP) experiment [2], a Gas Puff Imaging (GPI) optical diagnostic [3] has been installed. The GPI measures the HeI light fluctuations from the neutral Helium puffed in the plasma edge, in the radial-toroidal *(r-z)* plane, that is the plane perpendicular to the main RFP magnetic field component at the edge. The fluctuations are measured along 32 lines of sight that allow a 2D tomographic reconstruction of the emission structures. A tomographic algorithm has been developed to invert the 32 line-integrated signals, in order to obtain the 2D emissivity structures *e(r,z)* [4]. The emissivity is decomposed in Fourier modes as:

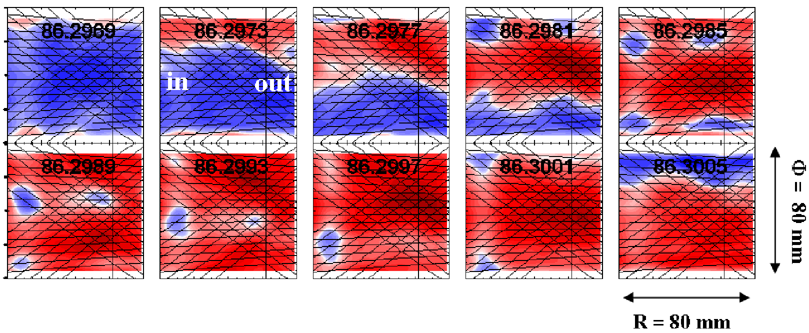

***Fig1:** 10 frames of the reconstructed 2D HeI emission in the toroidal (Φ) radial (R) plane during a DRE. The vertical black line is the position of the vacuum vessel.*

$$e(r,z) = \sum_{pq}\left[C_{pq}\cos\left(\frac{p\pi z}{\Delta z}\right)\cos\left(\frac{q\pi r}{\Delta r}\right) + D_{pq}\sin\left(\frac{p\pi z}{\Delta z}\right)\cos\left(\frac{q\pi r}{\Delta r}\right) + \right.$$
$$\left. + E_{pq}\cos\left(\frac{p\pi z}{\Delta z}\right)\sin\left(\frac{q\pi r}{\Delta r}\right) + F_{pq}\sin\left(\frac{p\pi z}{\Delta z}\right)\sin\left(\frac{q\pi r}{\Delta r}\right)\right]$$

In this way, together with the images of the edge coherent structures ("blobs") (an example is shown in fig1), the energies and the phases of the Fourier modes can be studied. Thanks to the high time-resolution (the sampling frequency is *10 MHz*), the dynamic of the edge turbulence can be resolved, and from the time-variation of the phase of the inverted modes, the toroidal velocity can be obtained. Because of the high time resolution, the link between the edge structures and the magnetic fluctuations can be studied in detail. The correlation between the two phenomena is clear in fig2, where the fluctuations (measured with the in-vessel sensors [5]) of the toroidal magnetic field δB_ϕ (a), and the GPI quantities (b-d) are shown.

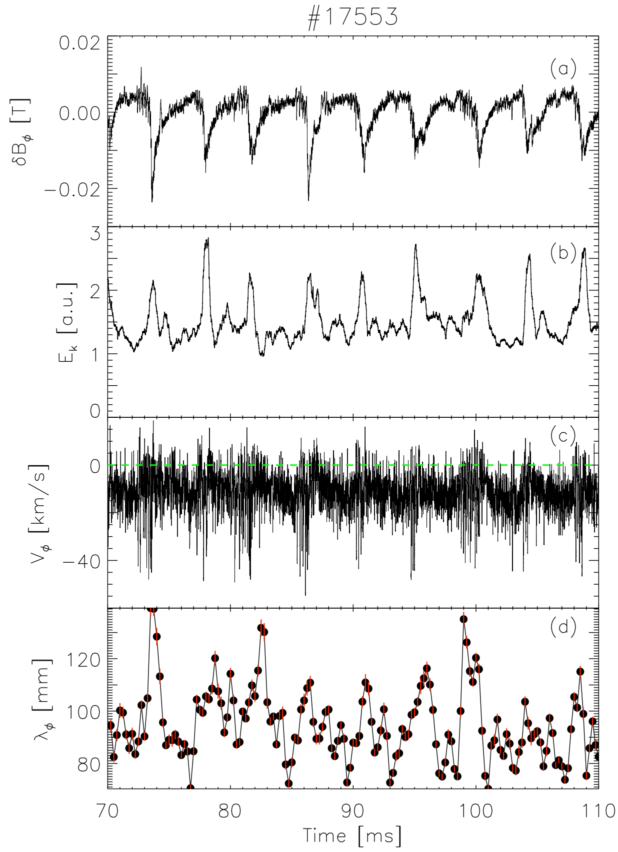

Fig2: *(a) toroidal magnetic field fluctuations; (b) total energy of the toroidal modes of the tomographic reconstruction; (c) toroidal velocity of the edge fluctuations; (d) toroidal correlation length.*

The strong magnetic fluctuations are the poloidally symmetric (*m=0*) Dynamo Relaxation Events (DREs), large magnetic reconnection events. The increasing of the mode energy related to the 2D GPI tomographic inversion (fig2(b)) in correspondence of the DRE suggests an increasing edge turbulence level. At the same time, the toroidal velocity of the fluctuations measured from the phase of the inverted modes (c), shows higher fluctuations that are not present between two DREs. The magnetic perturbation could change the ion losses toward the wall, therefore during DRE the radial electric field profile is modified, as confirmed by Langmuir probes [6], and the consequent modification of the ***ExB*** flow could change the velocity of the edge structures measured by the GPI. In the panel (d) of Fig.2 it is shown that the toroidal correlation length increases during the DRE. This correlation between the edge turbulence and the magnetic fluctuations has been already described [7], however by applying to the GPI data the tomographic reconstruction method allows to study it in

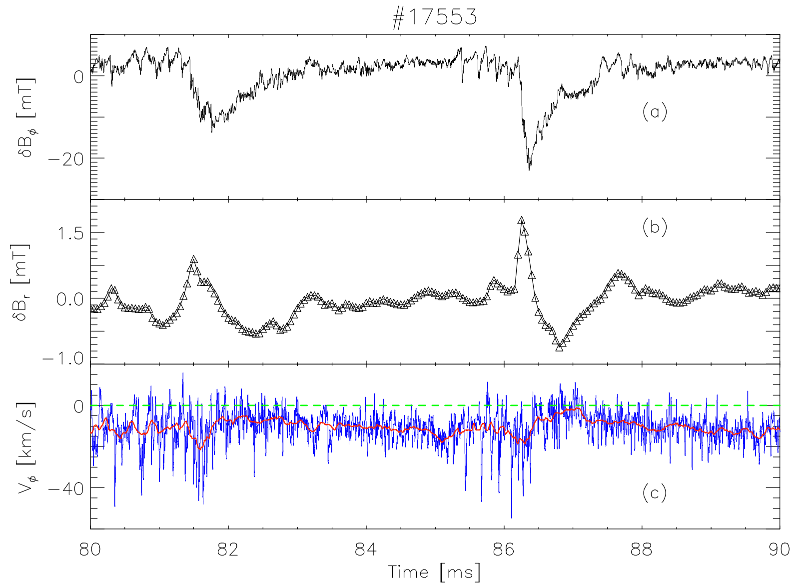

Fig3: *Zoom of two DREs. (a) δB_ϕ; (b) δB_r; (c) toroidal velocity*

more detail, especially for what concerns the high frequency fluctuations. These fluctuations are shown in figure 3, (which is a zoom of Fig.2). The fluctuations δB_ϕ (a) are associated also with the radial magnetic field δB_r (b), and the relation between the two components confirms that the DRE can be interpreted as a poloidal current sheet that propagates along the toroidal direction [6]. The panel (c) in Fig.3 shows the toroidal velocity v_ϕ, evaluated with a time resolution of *5 μs*. An average value of about *-15 km/s* along the ***ExB*** drift is obtained. About *0.5 ms* before the magnetic reconnections, v_ϕ begins to fluctuate between *–40* to *+10 km/s*, approaching *0 km/s* when the radial magnetic field is negative. The quasi-periodic velocity fluctuations before the DRE seems to be strongly correlated with the small fluctuations in δB_ϕ.

As shown in figure2 and 3, the edge turbulence measured by the GPI is modified by the DRE only if it is sufficiently strong. The modification is clear when $\delta B_\phi \sim 20mT$; for magnetic fluctuations of smaller amplitudes this interaction is less evident.

Beyond the modification of the radial electric field in the plasma edge, other mechanisms could play a role in the modification of the edge turbulence: in particular, if the edge blobs are associated to a poloidal current sheet [8], the magnetic field can interact directly with them. This could explain the clear relation between the fast fluctuations in δB_ϕ and the time-behaviour of the toroidal velocity. In fig4 an even shorter time window around a single DRE is shown, with the velocity fluctuations (b) before and during the magnetic reconnection. Fig.4(c) highlights how the edge fluctuations detected in the raw GPI data involve all the chords, and that they pack near the minimum of the toroidal magnetic field; panel (d) shows the time behaviour of the phase of the dominant mode from which the toroidal velocity is evaluated. All this phenomenology suggest a direct coupling between the DRE (low-frequency MHD activity) and the edge turbulence.

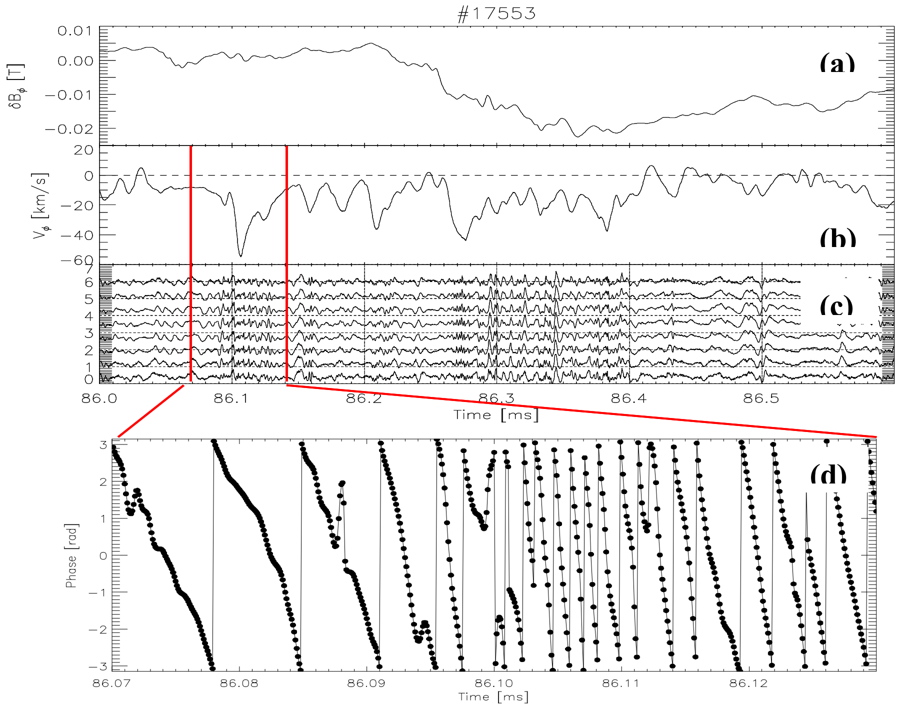

Fig4: *one DRE. (a) δB_ϕ; (b) toroidal velocity; (c) time behaviour of 8 toroidal lines of sight; (d) zoom of the inverted phase.*

In the attempt to resolve even better the link between the magnetic activity at high and low frequency and the blobs' dynamic, three new triassial magnetic sensors are installed in the same edge region viewed by the GPI.

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